THE 'NEW REDUCTIONISM' AND LEVELS OF 'EMERGENCE'.

(1) The 'New Reductionism'

In its approach towards the problems of life, mind and evolution, Physicalism, no matter what form it may take, imposes this demand upon those in search of explanations. At the bottom of everything, is the lex naturalis, the body of scientific law as currently recognised and universally accepted. That is to say, no extensions invoked *specifically* to account for the various goings-on within the organic realm are to be countenanced. Any such speculations are dismissed in advance as ad hoc evasions; to entertain them for a moment is to put oneself beyond the pale. Further, the whole of science itself, despite appearances to the contrary, is deemed to be physics -and nothing else but. Thus, physics is physics, chemistry is molecular physics, biology is a chemistry in which reactions have become inter-coupled vectors, while psychology is but highly dynamic molecular biology viewed though inverted opera glasses.

In this prospectus of physicalist *reductionism*, everything is ultimately physics -nothing else needs to be added. In the above hierarchical listing, the whole of the coherence which these disciplines embody may be thought of as an inverted truncated cone standing upon its apex. In passing from physics to psychology, things get more complicated, but that is all. To take such a position is not, physicalists claim, to assert that their science is complete; thus we have yet to come by a 'theory of everything' unifying the four forces of nature, while quantum physics and relativity must maintain their uneasy coexistence in the face of some awkward contradictions. Physics remains incomplete, but whatever additions may yet be called for must not, they demand, depart from the current *paradigm* of scientific law -as would be the case if they were invoked expressly in the service of life and mind. The organisation of science into the hierarchy of disciplines bearing other names is therefore to be dismissed as no more than a legitimate stratagem of convenience. In the earlier days, the unsavoury intruder of *consciousness* was dismissed as persona non grata. In more recent days it has been granted a grudging re-entrance -but only as a helpless bystander, thus leaving the autonomy of physics undisturbed.

In its original 'strong' form, physical reductionism demanded that everything emerging from the higher levels of the hierarchy of empirical disciplines should directly *follow from* the grounding principles of physics -which is to say a great deal more than that they be *consistent* with this foundation. Prior to 1931 this might have seemed to be a reasonable stand for physicalism to take. But in his seminal paper of that year, released upon a startled world, Kurt Gödel demonstrated conclusively that for any formal system as complicated as arithmetic, there exist true statements -actually an infinity of them- whose veracity cannot be derived from the axioms, postulates and primitives upon which the system is grounded, through any logical process of Peanoese mathematical 'induction'. That is to say -and this follows from the definition of the word- such true propositions or constructions are not *theorems* within the system. Their authenticity must be established by other -perhaps uniquely tailored- proof processes. Their truth having been established, however, they *may* then be *assigned* to the system's foundations, so that they become, by fiat, theorems within the expanded formalism.

If this be true of the system of arithmetic, then how much more must it be the case for analysis (ie. calculus and its derivatives] and hence the physics which this advanced formalism plays so large a part in underwriting? In contrast, for strong reductionism to have held, analysis would need to have the kind of simplicity of Euclidean geometry -in which all true propositions are automatically theorems, that is, are nothing more than tautological extrapolations from the system's foundations.

What the post-Gödel reductionists are saying is that in order to explain and account for the behaviour of arbitrarily complex entities -such as a living cell or the network of neurones within the cerebral cortex- more is needed than a thorough knowledge of Natural Law. The formal nature of the configuration together with the ambient boundary conditions must also be taken into account. Sometimes their effect upon system performance can be foreseen and defined in straightforward mathematical or logical terms. This ceases to be true of the more challenging of these entities due to their embodiment of two parameters of complexity rich in their promise of 'interesting' and intractable behaviour. The first is 'non linearity'. Scott (1996) characterises the distinction between linear and nonlinear systems as follows:

"...Suppose that a series of experiments on a certain system shows that cause C_1 gives rise to effect E_1; thus

$$(C_1) \text{---> } (E_1)$$

and similarly

$$(C_2) \text{---> } (E_2)$$

expresses the relationship between cause C_2 and effect E_2 , where the arrow indicates the action of the system which is being studied. Mathematicians say that the system is *linear* if

$$(C_1 + C_2) \text{---> } (E_{1,2} = E_1 + E_2)$$

which tells us that the two causes acting together $(C_1 + C_2)$ leads to an effect $(E_{1,2})$ that is the sum of the two individual effects $(E_1 + E_2)$. The whole is equal to the sum of its parts.

For a *nonlinear* system on the other hand, the whole is not equal to the sum of the parts. In symbols,

$$(C_1 + C_2) \text{---> } (E_{1,2} \neq E_1 + E_2)$$

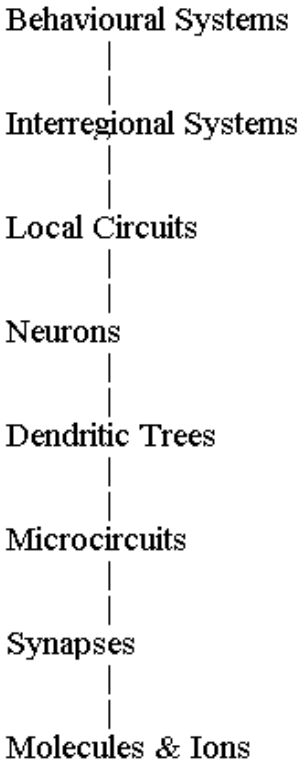
which tells us that the effect of the two causes acting together is not the sum of the individual effects." 1996 p486

In other words, in a nonlinear system, the *whole cannot be explained as a sum of the parts.* The term 'holism' is sometimes applied -in proportion as the interactions between the effects of the parts be deeply entangled. Strongly recursive nonlinear systems may, despite their strict determinism, display startling and quite unpredictable patterns of behaviour.

The second parameter of interest is that of *hierarchical organisation* in which the configuration is put together bottom-up in a succession of stages each of which makes a unique contribution to the resulting behaviour of the whole. Dawkins offers the following informative example of such a hierarchical ladder:

".....The nonexistent reductionist, the sort that everyone is against, but who exists only in their imaginations- tries to explain complicated things *directly* in terms of the *smallest* parts, even, in some versions of the myth, as the *sum* of the parts! The hierarchical reductionist, on the other hand, explains a complex entity at any particular level in the hierarchy of organisation, in terms of entities only one level down the hierarchy; entities which, themselves, are likely to be complex enough to need further reducing to their own component parts. It goes without saying.....that the kinds of explanations which are suitable at high levels in the hierarchy are quite different from the kinds of explanations at lower levels. This was the point of explaining cars in terms of carburettors rather than quarks. But the hierarchical reductionist believes that carburettors are explained in terms of smaller units...., which are ultimately explained in terms of the smallest of fundamental particles. Reductionism, in this sense, is just another name for an honest desire to understand how things work". Dawkins 1986 p13

Closer to our present interests is Shepherd's (1991) p291] characterisation of the formal ladder within the cerebral cortex:



The title of Scott's recent book, Stairway to the Mind, says it all, leading predictable to his formula for a successful mastery of the mysteries of mind. Since each level within the organisational hierarchy makes its own unique contribution to make, then what is called for is a meeting of minds between experts who have specialised in their corresponding fields:

"...Like life, the phenomenon of consciousness is intimately related to several levels of scientific hierarchy, so the appropriate scientists -cytologists, electro physiologists, neuroscientists, cognitive scientists, psychologists, psychiatrists, neurologists, anaesthesiologists, sociologists, and ethnologists- should be working together. It is difficult to see how this elusive phenomena might otherwise be understood".p184

And so, finally:

".....The idea that all can be reduced to the spare concepts of physics and chemistry has been exposed as untenable because each level of the hierarchy is dynamically independent of its neighbours. Dynamic independence -in turn- arises from *non linearity* which induces the *emergence* of new and qualitatively different *atomistic entities* at each level". p 186

In referring to this hierarchy of levels within the brain, Scott (1966) goes on to claim:

"……It is difficult to put any bounds on the nature of mental phenomena that might emerge fromclassical non-linear science…..the study of hierarchies of such sytems has barely begun, and the qualitative natures of ther phenomena are largely unknown"

Those championing the New Reductionism have been vehement in their insistence that no new grounding principles, laws or agents are being appealed to, or have been assumed to emerge Deus ex machina, and that above all, they have not fallen into the heresy of vitalism.

".....Life sciences must deal with general, progressively more complex levels of biological integration.....Some scientists cling to the reductionist faith -that the way to know everything is to concentrate on the investigation of the lowermost level, which is consequently styled the 'fundamental' level. A wiser and sounder strategy of scientific research is to gain an understanding of the phenomena and regularities on all integration levels. This is not because some new and irreducible agents manifest themselves in life as compared to the inert matter, or in man as compared to the biological world, as some vitalists wanted us to believe. It is simply because every level of organisation shows an integrative patterning of components from the underlying levels, and these patterns are, in turn, the components of the higher, or, if you wish, less fundamental levels. Now the patterns as well as their components equally deserve attention and study". Theodosius Dobzhanski [date?]

Scott (1995) quotes Schrödinger to the same effect (from Schrödinger 'What is Life?:

".....From all that we have learned about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to the ordinary laws of physics. And that is not on the ground that there is any 'new force' or what not, directing the behaviour of the single atoms within a living organism, but because the construction is different from anything we have yet tested in the laboratory". p.40

Crick makes an even stronger appeal:

> " ...Crick emphasises the importance of emergent phenomena, a term which can be used in two senses. The first implies behaviour that cannot be understood in any way and thus has mystical overtones. The second sense, which he uses, implies that 'while the whole may not be the simple sum of separate parts, its behaviour can, at least in principle, be *understood* from the nature and behaviour of its parts *plus* the knowledge of how these parts interact'". Scott (1995) p38

At this point it might be helpful to distinguish and appropriately name two different categories of *emergence* . We might call those surprises which stem solely from organisational complexity and the ambient boundary conditions 'Gödelian' because they take their origin entirely within the accepted system, dubbing those which cannot be so accounted 'Trans-Gödelian'. or simply *Strongly* Emergent. The appearance of strong emergence automatically implies that the underlying formal principles upon which the phenomena were taken to be grounded are inadequate or insufficient. For example, there is no way in which the appearance of a perpetual motion machine can be accounted for merely by an appeal to a 'sufficient and appropriate' complexity. If such a machine were ever to be produced then we should be driven to conclude that the lex naturalis was due for a reexamination. One does not have to look far, historically, for such examples. A century or so ago, it became increasingly evident that gravitational attraction alone was unable to account for the sun's continuing luminosity, suggesting that the physics of the day must be incomplete -which, of course, is precisely what turned out to be the case. Here we have an instance where strong emergence is mass-dependent; an astronomical body must exceed a critical mass before thermonuclear reactions can take hold, that is, before the sequestered 'strong force' can become manifest.

Within the context of the mind/brain dilemma and the ability of machines to imitate brains, Lucas distinguishes between the two levels of emergence in the following terms. I have not hesitated to quote Lucas at length on this important matter:

> ".....When we increase the complexity of our machines there may, perhaps, be surprises in store for us. (Turing) draws a parallel with a fission pile. Below a certain 'critical' size, nothing much happens: but above the critical size, the sparks begin to fly. So too, perhaps, with brains and machines. Most brains and all machines are at present 'sub critical' --they react to incoming stimuli in a stodgy and uninteresting way, have no ideas of their own, can produce only stock responses-but a few brains at present, and possibly some machines in the future, are super-critical and scintillate on their own account. Turing is suggesting that it is only a matter of complexity, and that above a certain level of complexity a qualitative difference appears, so that 'super-critical' machines will be quite unlike the simple ones hitherto envisaged.
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> "This may be so. Complexity often does introduce qualitative differences. Although it sounds implausible, it might turn out that above a certain level of complexity, a machine ceased to be predictable, even in principle, and started doing things on its own account, or, to use a very revealing phrase, it might begin to have a mind of its own. It would begin to have a mind of its own when it was no longer entirely predictable and entirely docile, but was capable of doing things which we recognised as intelligent, and not just mistakes or random shots, but which we had not programmed into it. But then it would cease to be a machine, within the meaning of the act. What is at stake in the mechanist debate is not how minds are, or might be, brought into being, but how they operate. It is essential for the mechanist thesis that the mechanical model of the mind shall operate according to 'mechanical principles', that is, that we can understand the operation of the whole in terms of the operations of its parts, and the operation of each part either shall be determined by its initial state and the construction of the machine, or shall be a random choice between determinate operations. If the mechanist produces a machine which is so complicated that this ceases to hold good of it, then it is no longer a machine for the purposes of our discussion." J.R.Lucas.[date ?]

The distinction, then, between the two levels of emergence is a subtle one, requiring that we keep our wits about us; as many have noted, its casual usage has been an unending source of mischief. Scott himself ruefully asks: " Have we carelessly become 'crypto-animists' or mystics pretending to be naturalists?" Hut has drawn attention to a way in which the term is often taken which offers the seductive promise of executing an authentic deus ex machina.

> "Why should anything dissimilar 'emerge' from a given substratum, spontaneously generating their own complexity as mice were thought, not so long ago, to be generated spontaneously from an old shirt?....Calling something an emergent property after witnessing higher structure formation coming out of a computer simulation with lower structure as sole input, is that supposed to explain something? Life 'emerges' out of lots of molecules; consciousness emerging' out of lots of nerve cells. Well, why not consider time as emerging out of clocks? Without clocks, no accurate time measurement. And a good clock provides excellent correlation with the flow of time. But time, surely, does not emerge out of a clock" Hut & Van Fraassen (1997) p.187

In other words, there is indeed a strong emergence --the strongest there is- in which one category appears from another. What is apt to pass unnoticed is that the emergence is in the mind of the observer, and not 'out there' in the mechanism. It is an emergence of *meaning* which doesn't 'shine' (for the non-watchmaker) from the pile of cogs levers and jewels which are seen to be nothing more than what they are.

So sharp a mind as John Searle's seems to have fallen foul of just such a fallacy in his attempt to come to terms with the mind-brain relationship while remaining within the confines of his own exegesis of physicalism. He offers a simple analogy. Consider everyday liquid water -H_2O. At the microscopic level is the substance which physics has painstakingly revealed to us -but which is beyond direct perceptual access. It is an endless microscopic dance of arbitrarily large populations of molecules -plus a few evanescent ions, the molecules in question being composed of atoms not at all resembling the miniature quasi-spheres which they were once taken to be. At the same time, its character viewed from a macroscopic perspective is quite different, as we all know from our direct experience. It is a continuum with properties of 'wetness', a high surface tension responsible for the way it splashes and forms droplets. It has its own taste quality and hydrodynamic properties which we directly sense everytime we enter the ocean for a swim. Water, so to speak, is an entity which *stretches* across a scale-continuum; it has a kind of polarised presence with a top end resting upon a bottom end.

With this analogy under our belts, Searle now addresses the mind-brain problem. The brain, Searle asserts, is -in all ways save one- an *organ* 'just like any other'. As such, as with the case of water, it is scale-polarised with a bottom end of circulating waves of depolarisation within the complex reticulum of the 'enchanted loom', along the nerves comprising its 'enchanted loom' But macroscopically, all of this activity fades from view, being replaced by a kind of integral overview manifesting, in visual perception, for example, as a flow of (comparatively) narrow-band images. The unique property of the brain organ, Searle asserts, is that the 'upper level' of the scale-continuum bears consciousness epiphenomenally. All of behaviour is to be accounted for in terms of brain mechanisms which are conscious at the macro end and 'neural' at the bottom. By this means, Searle believes that he has provided a means of coming to terms with the mind-brain relationship without disturbing the canons of science -allowing only an epiphenomenalism of non-efficacious consciousness. Raymond Tallis (1994) waxes caustic over this piece of leger de main:

> ".....The notion of the causal interaction between mind and body as being as essentially the same as a causal interaction between descriptions is rather obscure. Searle believes, it seems, that when matter acts upon mind (to alter mental states) or mind acts upon matter (to bring about intentions) it is a question of one description of a system acting upon another -as if the level of description of the system were not only part of the system (which of course it is not) but also enables the system to interact with itself. Without such levels of description or observation, one must presume, matter could not give rise to mind, nor mind act upon matter." p.40)

Coming back for one more brief look at H_2O. Water 'out there' is indeed -more or less- as physicists describe it. But our sense organs which give us access to it are narrow-band, filtering out all but a threadbare ribbon of formal information. Upon arrival within the cortex, the neural impulses pick up a series of 'qualia' -characteristic forms of mental supervenience whose quality is a function of the sensoria and not of the stimuli. If perception had the character which the false but intuitively appealing doctrine of 'naive realism' demands, then 'qualia' would be 'out there' rather than 'in here'. Water *in itself* would indeed be scaled-polarised with the appropriate qualia shining from its upper macroscopic reaches. Here as elsewhere, the villain of naive realism has a lot to answer for. Limitations of space prohibit further discussion of this important matter. The interested reader will find a full account in Harrison (1989).

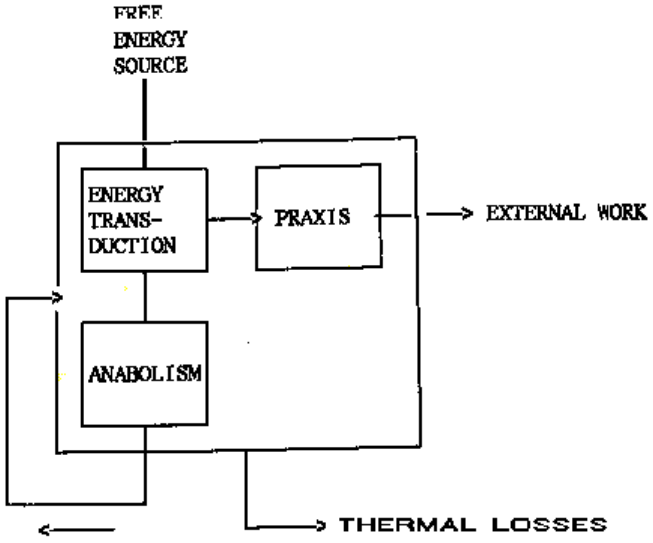
This then, is the thesis of the new reductionism. Can it stand its ground? It's a very tall order. Let's just look at the physical organism of each one of us. It requires that every level of complexity -biochemical, cytological, anatomical and physiological-flowed smoothly from few picograms of DNA -whose sequencing of base pairs constitutes the sole blueprint. It must account for the whole sweep of organic evolution through the mechanism of 'filtered noise' -not to mention the start-up of life itself where there was nothing for neoDarwinism to select *from.* Turning our attention now to that colloidal mass of recursive reticulation passing under the name of the cerebral cortex; Did relativity and for that matter, Gödel's theorem itself really emergence from such a physical entity unaided? To repeat -it's a tall order. Yet the physicalist feels he can deliver the goods, drawing confidence from a number of recent developments within mathematics which have seemed to him to open some promising doors. Many of these have passed into general circulation, becoming household words; neural networks, cellular automatons, Gabor transforms, self-organising criticality, catastrophe theory, fractals, holography, the new thermodynamics of Prigogine and chaos (particularly its 'edge'). Some of these have already been examined further above. It is now time to take a close look at Prigogine's 'new thermodynamics' and the nonlinearities of what Horgan (1996) collectively refers to as 'chaoplexity'.

(2) Prigoginiana

Entropy, those of my generation were taught at college, is something which heads remorselessly upwards tending towards a maximum equilibrium value from which the extremely unlikely stochastic reverses, of Poincaré type provide the only escape from boredom. This judgment remains true despite the discovery of the big bang which started in a state of very high chaotic entropy which was to head progressively downhill due to the formation of corpuscular matter, atoms, molecules, and the aggregation of matter into stellar bodies. But this pre-Boltzmann aspect of cosmogeny will fade progressively with the passage of time.

In his 'new look' at thermodynamics, what Prigogine was able to demonstrate during the course of studies terminating in a Nobel prize, was that appropriately constituted open systems standing sufficiently remote from thermodynamic equilibrium were capable of holding thermodynamic degradation in abeyance more or less indefinitely, given only a continuing access to a source of Gibbsian free energy. Such 'dissipative' modules maintain internal order at the expense of exporting disorder into the environment; they do their job through the agency of house-keeping and maintenance mechanisms. Living organisms are unquestionably quintessential examples of such systems. Other modules channel free energy into the execution of useful work upon the environment. Figure 2 below illustrates the corresponding entropy and energy flows archetypal to living organisms.

> ".....When a system is constrained far from equilibrium, macroscopic order arises not as a violation of the second law of thermodynamics, but as a consequence of it. Creationists are wrong, accordingly, when they still tout the contradiction between the second law and evolution that entangled 19th century minds. There would be a contradiction if living systems were so simple or so random that, like atoms in a gas, they hover around and quickly access thermodynamic equilibrium. If anything is clear by now, however, it is that living systems are virtual paradigms of systems that are constrained away from equilibrium and that they pay what they owe to the second law by building internal kinetic pathways that send things in the environment, instead of themselves to thermodynamic equilibrium. Depew and Weber 1995.p464



The Prigoginian thermodynamics discussed above is strictly conservative; nothing has so far been said about how such systems could ever have come into existence in the first place. Maintaining order is one thing, creating it quite another. Maintenance calls only for the continuing availability of Gibbsian free energy while its creation demands access to a source of sufficiently powerful structuring 'information' (in the Shannon-Weaver sense). As Schrödinger might have put it, to acquire significant coherence demands access to *two* kinds 'negentropy', the one energetic and the other *informational*, and *no excess of the first can compensate for a lack the second.* Free energy of itself cannot generate form or produce order out of chaos. Bertalanffy made this very clear a quarter of a century ago, but his words seem to have fallen upon deaf ears.

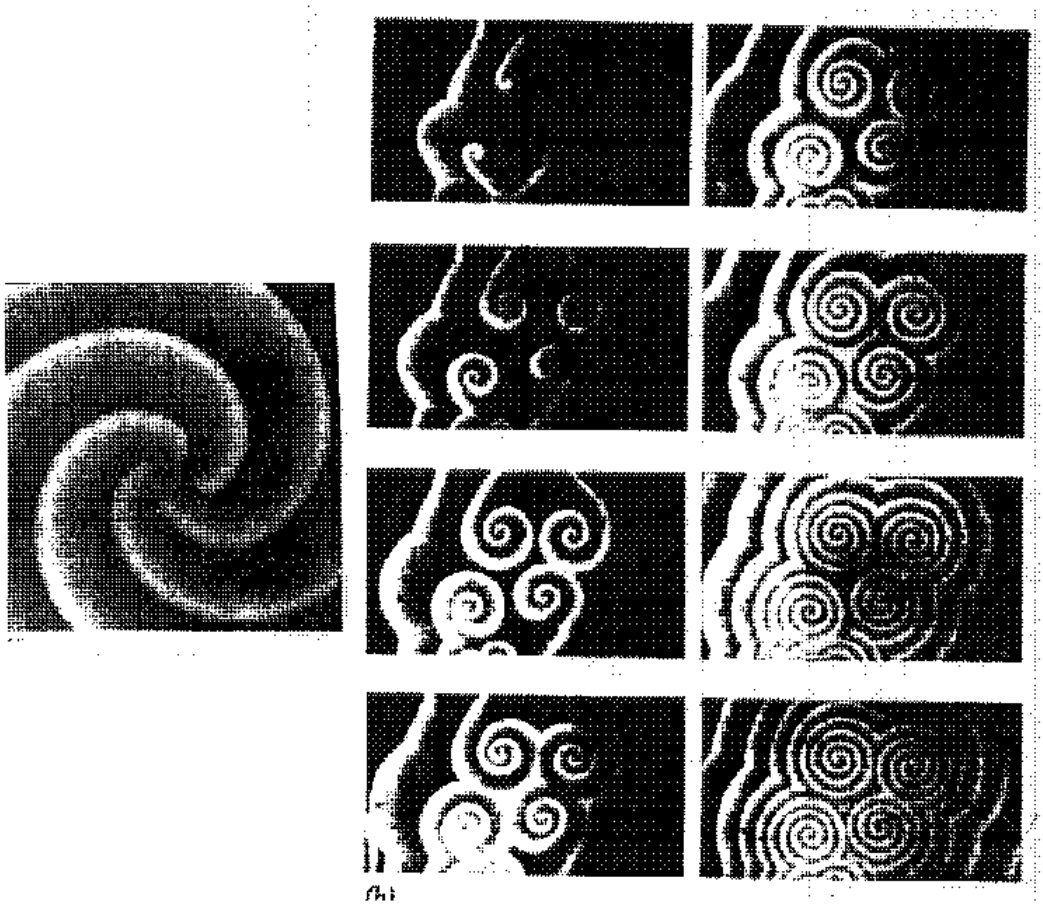
> ".....Considered thermodynamically, the problem of neoDarwinism is the production of order from random events. Order and local decrease in entropy can, of course, take place if 'organising forces' are present (eg. the formation of a crystal in a solution due to lattice forces). In the absence of such forces, the principle of thermodynamics and its equivalent in information theory (Shannon's Tenth Theorem, stating that information can be converted into noise, but not vice versa) will prevail".(1972) p.73

As he goes on to point out, the situation is especially critical at life's origin:

> ".....What is at present quite inexplicable is why and how organic substances, nucleoproteins, or coacervates should have formed against the second principle [of thermodynamics] -systems tending toward thermodynamic equilibrium but 'open systems' maintaining themselves at a distance from equilibrium in a most improbable state. This would be possible only in the presence of 'organising forces' leading to the formation of such systems. Before such systems had emerged, selection could not even start to act". p 73

This is but one of a number hurdles facing all origin of life scenarios. Two others are questions of the continuing availability of adequate concentrations of source reagents and the horrendous logistics problem of moving reactants in and out of the 'reaction chamber' See Harrison (1999).

Where 'informational' negentropy *is* sufficiently available, order can arise out of chaos. One of the more spectacular -and oft-quoted- example is that of the Belousov/Zhabotinskii figures in which the confluence of appropriately constituted produces an evolving display of spirals -as illustrated in figure 3 An even simpler example is the creation of snowflakes from condensing water vapour.



Such examples prove their point but it is difficult to see what they have to contribute to real world problems of life mind and evolution. Consequently, statements such as the following can only be dismissed as exercises in arm waving

> "....At the AAAS symposium, much was made of Prigogine's suggestion that evolution inevitably meant 'novelty and unexpectedness'.....The result tended to be a succession of speculations and generalities which, while intuitively one might think them true are not testable in any accustomed scientific way. Erich Jantsch not only admits this but revels in it:
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> > ".....The decisive point is that self-organising systems continually generate their own internal fluctuations, and test their stability and that it is these internal fluctuations when they become internally reinforced (through auto catalytic and other highly non-linear mechanisms), that drive the system over an instability threshold to a new structure. There is no stability, period; only metastability or delayed evolution. .....Evolution is *self-transcendent* that is to say, always ready to reach out beyond the system's own boundaries, *without any need*, just for the joy of it. Only then can evolution be understood as *creative* and not adaptive". Hitching page 163

A decade or so later, we find phantasies of much the same kind being bruited abroad:

> ".....The words *fluctuation* or *disturbance* have been used throughout this book, meaning a slight change in the conditions of a system. If such processes are endogenous, random and

> spontaneous, we are dealing with fluctuations. The role of fluctuations is of crucial importance for the onset of self-organisation in a homogeneous but unstable system. The analysis of fluctuations in nonlinear systems is an important and fast-growing field. Self organisation may arise in some stable systems only if they are perturbed by external fluctuations. The sensitivity of non-linear chemical reactions to very small external influence is also investigated"
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> Babloyantz 1986 p329

Indeed, but one is left asking -how did these far more subtly organised systems ever boot-strap themselves into existence, that is, systems which are hierarchically organised in such a way that a powerful central generator serves as a source of an envelope of options from which useful selection may be made? And how, finally, is this central nucleus to be enhanced when its resources are exhausted? Cats do not come with bells preattached. If they did, it might be a different story.

Prigogine's views have long been entertained by the faithful with something like religious fervour; the AAAS symposium referred to above was held many years ago but things have changed little since then:

> "....At the faculty lounge, Prigogine and I were joined by a dozen or so other researchers employed at his centre: . We assembled at a long rectangular table. Prigogine sat at the middle of one side, like Jesus at the last supper, and I sat beside him, like Judas, listening along with everyone else, as he held forth.
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> "Sporadically, Prigogine called on one of his disciples to say a word or two -enough to draw attention to the vast gap in rhetorical powers between his and theirs. At one point, he asked a tall cadaverish man sitting across from me to explain his non-linear, probabilistic view of cosmology. The man dutifully unburdened himself, in a lugubrious eastern European accent of an impenetrable monologue about bubbles and instabilities and quantum fluctuations. Prigogine quickly stepped in. The meaning of his colleague's work, he explained, was that there was no stable ground state, no equilibrium condition of space-time; thus there was no beginning to the cosmos, and there could be no end." Horgan (1996) p.219

In summary, what Prigogine is asking us to believe is that through his ministrations -in which he sought 'the re-enchantment of nature'- Boltzmann has been stood on his head, becoming transformed in the process from an implacable enemy into a resourceful ally. The plain fact of the matter, however, is that he continues to stand, right way up, with his feet planted firmly on terra firma. There is no free lunch, after all.

(3) 'Chaoplexity'

Nonlinear systems put together from nonlinear differential equations Boolean networks or other appropriate generators, lean strongly towards mathematical recalcitrance, that is to say, are resistant to solution in 'closed form'. This means that their state at any time t cannot be determined by straightforward calculation but only through a progressive brute-force extrapolation from the initial conditions. The trouble is that as one proceeds, repeated operations of multiplication and exponentiation cause the numbers to increase in length indefinitely, eventually exceeding what the storage facilities are able to accommodate. From that point on, calculations will become increasingly approximate and the predictions correspondingly unreliable. Such is one of the factors frustrating our attempts at long-range (or even middle range) weather forecasting. Closed-form solutions, in contrast, give predictions whose accuracy bears little relationship to the extent of the future reach[1].

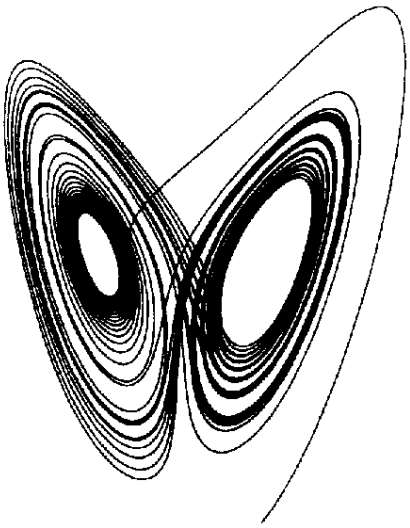

Figure 4 , reproduced from Penrose (1995) p22 is an early example of a chaotic system. Activity moves back and forth between the left and right lobes of this so-called 'Lorenz attractor' in an apparently random fashion -though this display stems from a simple differential equation. But such systems are pseudo- rather than truly random; appearances to the contrary, they are strictly deterministic, which means, among other things, that a re-run from precisely the same initial conditions will produce an identical phenomenal trajectory. Notwithstanding, it may take no more than an infinitesimal change in starting values to produce a dramatic rapid divergence in performance. Penrose (1995) p22 gives an interesting example. Suppose you have a line of 5 well- but slightly irregularly spaced balls on a billiards table. The problem is to pocket the end ball by cuing the first. The outcome is so highly levered upon the precision of the initial impact that, as Penrose puts it, a cough in the next room might be sufficient to cause a miscarriage in the sequence of events.. Yet were the player to *precisely* duplicate the cue stroke, the ball would end up in the pocket, as before. This requirement of strict determinism, as we shall see later, is not easily met where it is most needed, being one of the factors undermining the credibility of the chaos paradigm in accounting for important phenomena of life and mind.

Such non-linear systems when strongly recursive and inter-coupled with positive and negative feedback loops may behave in ways which are surprising and even startling. None-the-less, such 'emergence' is purely Gödelian in the sense defined, calling upon no mysterious extensions to natural law or to the foundations of mathematics. It is undoubtedly the promise of 'reducible' mystery which lies behind much of the very strong appeal which chaotic systems make to the minds of physicalist intellectuals. Thus for example, the cerebral cortex is a very richly interconnected anastomotic network occupying a lattice space of high dimensionality. Though the interactions between neural elements are not highly nonlinear, the numbers are huge -of the order of 10^{10}- sufficiently so, the physicalist feels assured, to account for the unending string of surprises emerging from this enchanted loom. Writing in the parlance of Chaos, this is how Freeman (1993) views the situation:

> ".....Where do the neural patterns come from? How are they generated? Our answer is straightforward. A key to understanding brain function lies in the use of nonlinear dynamics to model the perceptual function of the olfactory system. In brief, we believe that the olfactory system maintains a global chaotic attractor.....with multiple wings and side lobes, one for each odour that a subject has learned to discriminate. Each lobe is formed by a bifurcation during learning, which changes the entire structure of the attractor, including the pre-existing lobes and their modes of access through basins of attraction. During an act of perception the act of sampling a stimulus destabilises the olfactory bulbar mechanism, drives it from the core of its basal chaotic attractor by a state transition, and constrains it into a lobe that is selected by the stimulus for as long as the stimulus lasts..."
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> ".....However, the paramount barriers to understanding are theoretical. First, it is necessary to grasp the hierarchical nature of neural activity, in which sensory input and motor output are expressed at the microscopic level of single neurones, but perceptual and other higher order events are expressed in macroscopic activity of masses of neurons...This distinction still escapes many neurobiologists, who fail to see the forest for the trees. In part, this agnosia seems to be reinforced by a prevalent view of the EEG .....as devoid of functional interest or significant information content, often being characterised as 'the roar of a crowd at a football game'.

> Second, it is essential to introduce and rely on the theory of nonlinear dynamics and chaos.....and in particular to recognise that deterministic chaotic dynamics creates information (in the Shannon-Weaver sense) as well as destroying it. How is it that a mass of interacting neurones can continually generate new spatiotemporal patterns, that have never before existed, yet that conform within definite limits to the constraints imposed by the purposes of the subjects and the environmental conditions in which they must live? Prigogine's (1980) aphorism about 'the emergence of order from disorder' captures the essence of the process by which a sought-for and recognisable odourant stimulus forces a change in a chaotic bulbar state and confines the trajectory of the olfactory system into a selected and meaningful orbit.
>
> "Further development of the physiology of perception along these lines will be slow and difficult. One reason is that the most interesting perceptual processing takes place in a six-layered neocortex, while most of the results I have summarised here have come from the three-layered paleocortex". Freemen (1993) p513

Note how the a simple attractor such as that of Lorenz illustrated above has become organised into a complex hierarchy of wings and side-lobes jointly creating an envelope of options for reactive and spontaneous behaviour alike.

Before subjecting these claims to critical examination, let us be clear just what the gist of the physicalist's argument really is. On the one hand, he has established that relatively simple recursive nonlinear systems can produce behaviour which may be complex, unpredictable, and at times surprising. And on the other, that the cerebral cortex is a complex recursive non-linear system in its construction, and which behaves, much of the time in a most nonlinear way. So, by an appeal of post hoc ergo propter hoc he feels that he has made good his case. There are however, three powerful counter-arguments any one of which is powerful enough, on its own, to win the day.

First of all, it has been demonstrated in an earlier chapter, the kind of problems which humans solve in a twinkling of an eye have, typically, an exponential dependence upon problem size, as a consequence of which real problems call for more computation than the cerebral cortex, acting as any kind of computer, could possibly deliver. To make good their case, therefore, the votaries of 'chaoplexity' must establish that the kind of nonlinear systems which they are proposing somehow bypass or dodge such exponential leverage. Admittedly, such systems are far from being completely understood, to the point where Penrose (1995) raises the faint possibility that *taken to some asymptotic limit* such systems may even mimic the kind the kind of non-algorithmic activity underlying self-organisation and creativity:

> ".....can it be that *chaos* provides the needed answer to the mystery of mentality? For this to be the case there would have to be something completely new to be understood about the way in which chaotic systems behave in certain situations. It would have to be the case that in such situations a chaotic system can closely approximate *non-computational behaviour* in some asymptotic limit -or something of this nature. No such demonstration has, to my knowledge, ever been provided. Yet it remains an interesting possibility".

Evidently, Penrose himself is sceptical on this point, and I would insist that the proponents of such lines of argument be disbarred from invoking a 'mechanisms of the gaps' plea; we must demand that the no-man's-land is not to be taken by theft but only earned by honest toil. I can find no reason to believe that whatever non-algorithmic alias just might lie at the 'asymptotic limit' at the end of the 'chaoplexity' rainbow will produce *that* kind of nonlinear behaviour so characteristic of human performance, for example. Chaotic systems are intriguingly mysterious -something they share, for example, with the Mandelbrot set. But we must be wary of glib inferences which rest upon a sotto voce assumption that all mysteries are equal -so that one mystery may account for another.

A second cause for scepticism is the *character* of the behaviour issuing from chaotic systems. Left to their own devices the surprises which such systems sometimes throw out at us are simply not reminiscent of life and mind; they seem to offer no hint of any putative teleological look-ahead or purposeful intent. Again, it must

be emphasised that there is a double requirement here. Not only must the kinds of nonlinear abstractions which are under current study *behave* in ways which are promising and suggestive; as Penrose wouold say, they are not *usefully* unpredictable. In addition, they must somehow put themselves together, and grow progressively, climbing the ladder of organic complexity through some very mysterious process of *auto-supervenience*. Again, the onus of proof must be laid squarely upon the shoulders of the intellectual incumbents.

The third of my three grounds for scepticism is of an entirely different kind. The modelling paradigm of chaos demands that the nonlinear systems in question be *deterministic* Noise *within their foundations* would quickly erode the odd coherence and surprising trajectories which typically characterise true chaotic systems. But noise is precisely what the activity of the cortex is grounded upon; synaptic operations at the heart of the enchanted loom are wet and sloppy. Notice, however, that all of this is not to imply that noise may not have a part to play -*after the fact*, so to speak. Thus a system which is deterministically *grounded* may embody an organisation which is *macro-sensitive* to the boundary conditions outside. High level noise (in their terminology, 'fluctuations') inveighing upon the system from its surroundings far from degrading its behaviour may drive it into other channels.- To repeat a quotation already given above:

> "...The words *fluctuation* or *disturbance* have been used throughout this book, meaning a slight change in the conditions of a system. If such processes are endogenous, random and spontaneous, we are dealing with fluctuations. The role of fluctuations is of crucial importance for the onset of self-organisation in a homogeneous but unstable system. The analysis of fluctuations in nonlinear systems is an important and fast-growing field. Self organisation may arise in some stable systems only if they are perturbed by external fluctuations. The sensitivity of non-linear chemical reactions to very small external influence is also investigated"
>
> Babloyantz (1986) p329

The related discipline of fractals are, I believe, of less relevence to the present discussion. A brief comment has been added in a footnote[2]

I will conclude this discussion with a brief look at the widely acclaimed attempts of Stuart Kauffman to apply chaos theory to the vexed problem of the origin of life; At the time Kauffman entered the scene, Kauffman was provoked into embarking upon his particular line of inquiry by what he perceived to be insuperable obstacles in the odds-on favourite -that life started with the emergence of a self-reproducing molecule -perhaps RNA or something related to it. In Kauffman's judgment, life is intrinsically and necessarily complicated. Arriving at a *self-replicating* polymer is unlikely enough, but if you were lucky enough to succeed, how could you ever walk yourself up from there to the simplest cell, with all of its irreducible histological and biochemical complexity? For that matter, could things ever really get started at all?

> ".....Grant that such a fine molecule arose. Could it maintain itself against mutational degradation? And could it evolve? The answer to both questions seems to be no. The self-replicating ribozyme would necessarily produce mutant variants. But those mutant variant ribozymes themselves are likely to be less efficient than the normal, or wild type, and hence are likely to make errors more frequently.....over cycles the system could produce a runaway system of mutant variants. If so, the original ribozyme with its ability to faithfully reproduce itself and others, would be lost in a flurry of sloppy catalysis heading to a system of RNA sequences that are catalytically inert. Life would have vanished in a runaway error catastrophe."
>
> Kauffman (1995, p.41)

Kauffman has long been engaged in the exploration of the fascinating and quite unexpected properties exhibited by large-scale systems organised in accordance with certain rules. His 'Origin of Life' speculations may be taken as a spin-off from his extended 'complexology' studies. What he has proposed is essentially a graphical model, in the 'graph-theoretic' sense, of a topological structure consisting of nodes interconnected by arcs. The nodes correspond to chemical compounds and the arcs to possible transformations between them. The chemicals may be merely substrates but at least some of these are required to be catalytically active with respect to one or

more of the transformational processes within the network. Typically they will be enzyme, or enzyme-like polymers, although a few may owe their activity to templating processes.

Central to his scheme of things is the way in which the success of such an ensemble is highly levered upon the *size* of the network, that is, upon the total number of polymers (or other putative catalysts and substrates) which are present. For example, as this number n goes up, the number of possible synthetic and transformational pathways between them goes up by the square (if we include the possibility of auto catalysis). Again, as the size of the polymers (in terms of the number of monomers they contain) goes up, so does the number of synthesis routes by which they may be put together; the size dependency here is even more highly levered. Perhaps the easiest visualisation here would be the synthesis of proteins from a small set of amino acid monomers.

The argument then proceeds as follows. Let's assume that a given polymer has a probability of only 10^{-6} of catalysing any one such reaction or transformation. Then, in a system large enough to offer a million potential transformational pathways, the system as-a-whole, Kauffman argues, should become self-sustaining:

> ".....At that diversity, on average such polymer will catalyse one reaction. A million to one multiplied by a million equals one. When the ratio of catalysed reactions to chemicals is 1.0, then with extremely high probability.....a web of catalysed reactions will form a collectively auto catalytic set of molecules." Kauffman (Ibid. p.63/4)

Or, more generally,

> ".....When the number of catalysed reactions is about equal to the number of chemical dots [compounds located at the nodes of the graph], a giant catalysed reaction web forms, and a collectively auto catalytic system snaps into existence. A living metabolism crystallises. Life emerges as a phase transition." (Ibid. p.62)

Clearly, size and complexity is of the essence, so that we need to have this present from the start; scaled-down systems aren't going to do much for you:

> ".....In this view of the origin of life, a critical diversity of molecules must be reached for the system to catch fire, for catalytic closure to be attained. A simple system with 10 polymers in it and a chance of catalysis of one in a million is just a set of dead molecules. Nothing happens in the inert soup save for very slow spontaneous chemical reactions." (Ibid. p.64)

So, how large must the system actually be, if life is to issue forth? After dismissing viruses as not being truly alive, because they are incapable of independent existence, Kauffman notes that in Pleuronoma, the simplest organism known to be capable of independent existence, having the 'full complement of standard gear' -including nucleic acid, protein-synthesising machinery, a cell membrane and so on- calls upon a number of genes variously estimated to lie between a few hundred to a thousand.

Under the heading of 'An Unrepentant Holism' Kauffman concludes in a way calculated to reassure the reader that no ghost-in-the-machine or vitalism is being proposed:

> ".....This theory of life's origins is rooted in an unrepentant holism, born not of mysticism, but of mathematical necessity.....Life emerged whole, not piecemeal, and has remained so."
>
> ".....Auto catalytic sets exhibit the emergent property of holism. If life began with collectively auto catalytic sets, they deserve awed respect, for the flowering of the biosphere rests on the creative power they unleashed on the globe -awed respect and wonder, but not mysticism." (Ibid.p.69)
>
> ".....What I aim to show is simple but radical. I hold that life, at its root does not depend upon the miracle of Watson-Crick base-pairing or any other specific template-replicating machinery.

> Life at its root lies in the property of catalytic closure among a collection of molecular species. Alone, each molecular species is dead. Jointly, once catalytic closure among them is achieved, the collective system of molecules is alive." (Ibid. p.50)

> ".....How different is humanity's stance, if it proves true that life crystallises out almost inevitably in sufficiently complex mixtures of molecules, that life may be an expectant emergent property of matter and energy.....But we have only begun to tell the story of emergent order. For spontaneous order, I hope to show you, has been as potent as natural selection in creating the world." (Ibid p.71)

> So, finally, "If I am right, the motto for life is not We the improbable, but We the expected." (Ibid.p.43)

But things don't quite end there. Kauffman has made an empirico-mathematical study of networks in which the elements (molecules, genes, or whatever) interact through Boolean functions[3], in particular noting how small adjustments in the nature of this function may bring the system to the "edge of chaos":

> ".....The reason complex systems exist in the ordered regime near the edge of chaos is because evolution takes them there." (Ibid. p.90)

As has been the case with Prigogine, Kauffman has sought to conjure upward mobility out of a combination of the querky, unpredictable behaviour of complex recursive systems and the pruning discipline of natural selection.

What are we to make of Kauffman's scenario? For a start, *is* it less demanding than the standard 'self-replicating-RNA-Polymer-first' one? It may well be true that once you have a certain degree of complexity in existence, the path to further evolution would be smoothed. But any such advantage is massively counter-balanced, by the much greater difficulty of bringing this 'minimum' into existence in the first place -in comparison with that of producing a single self-replicating polymer. Recall for a moment how huge that minimum is. He's talking about at least hundreds of compounds. All of these need to have been brought into existence within an environment which continues to supply all of the starting ingredients in adequate concentrations. I leave the reader to make his own judgments.

But more serious than any of this is the scalar logistics under which his proposed scheme must labour, whereas in fact nothing less than a highly organised vector architecture would have any hope of delivering the goods; individual reactants would need to be linked together by something more substantial than words. What Kauffman is offering is a soggy bag of chemicals, whereas what the system cries out for is a highly organised network of channels between components to bring scalar chaos into vectorial life. This applies both to the basic reactions themselves and to the sources of packaged energy needed to drive endergonic polymerisation's up the energy gradient. We are not told how this mammoth logistics demand is to somehow be met by the meagre resources which he has to offer.

Kauffman has made some fascinating discoveries in what might be called Gödelian mathematics -the interested reader should consult note 2 for one such example- but I fail to see that they have anything to tell us about most of the perplexing problems we have been discussing.

(4) <u>The Need for 'Strong' Emergence</u>.

We may condense what has been reviewed so far above into the following syllogism: First, there's no question that we find ourselves confronted, in problems of life, mind and human interactions with processes which are non-linear -often dramatically so; Second, attempts to ground these upon Prigoginian thermodynamics and the new formalism of Chaos have fallen hopelessly short of the mark; ergo, something more than the 'Gödelian' emergence so far offered, must be appealed to. We need to face up to the fact that the scope of natural law as currently recognised and universally accepted is insufficient to meet the challenge; to put it differently, principles of 'strong' emergence which break out of the neoreductionist straight-jacket must be sought.

We need to start by recognising that explanations need to be found for two different classes of phenomena. First comes the *conservative* performance of life-forms at all of the levels of cytology, ontogeny and above all, of the mind/brain ensemble. And second, those phenomena involving true novelty, progressive self-organisation and creativity of every kind -as evidenced by biological evolution, the growth and education of the human persona from infancy to maturity, and above all by the sallies of genius. Coming to terms with the first is a scientific matter -ie is to be accounted for by science of *some* sort. The second, however, lies beyond the reach of *any* science because the manifestations in question are simply *non-algorithmic*. Few among those currently dominating the intellectual landscape have been willing to acknowledge this distinction or to confront creativity on its own terms; -Penrose's is the only name coming readily to mind.

Extensions to scientific law are *necessary* in accounting for all of the phenomena of life, mind and evolution. They are fully *sufficient* in accounting for latent mind, that which conserves the incarnate persona and its world-view during sleep. In addition, they are *asymptotically sufficient* in underwriting conservative *performances* of all kinds -those for which established skills and resident knowledge are adequate to handle. However, they have nothing to say about the concomitant conscious interiority; this is totally beyond their purview.

The exotic extensions to science for which I am pleading must furnish both a novel substratum and an appropriate *formalism* governing the rules by which hierarchical configurations of engrams which underlie the incarnate persona are put together. But the provision of appropriate principles of architectural construction is one thing; bringing an actual building into existence quite another. There are no blueprints hiding anywhere within exotic law which can only sustain but neither conceive nor build the mansions of mind. Once more, something else is required.

In coming to terms with the mystery of *memory* (or more broadly, *latent* mind), science alone will suffice. This is of no small epistemological significance since it suggests that we may gain a substantial foothold through speculations which turn a blind eye to the embarrassment of what subsequently happens when mind crackles into life upon reawakening. Given some idea about how exotic science *sustains* and *conserves* we would then be in a position to speculate upon the part it has to play in moving from the sleeping to the waking state. It must not be forgotten that memory preserves not just know-how and know-what but also the temperament, disposition and character traits of the mind's owner. While asleep, our minds and brains alike reside within the safe embrace of an enhanced science. It's all a question of substance, an appropriate mathematical formalism and the possibilities of delicate architectural construction; nothing further needs to be appealed to. No mysticism or 'vitalism' is being let in by the side door. Science is science, whether of run-of-the-mill or exotic sort.

But upon awakening from deep sleep, the rules change abruptly; exotic science, though still very necessary, is no longer sufficient. Something else must make entrance; some principle of enlivenment, quickening, and conscious interiority makes its entrance, giving rise to the gamut of *qualia*, the pull of teleology (so different from the push of causation), the possibilities of good and evil, agony and ecstasy, and at the limit, experiences of mysticism in which we appear, to ourselves, to be merged with the source of our conscious being. We have to come to terms with a *second category* which by definition lies beyond the purview of science of any kind. Yet the interface between the two categories of material mind and the warm interior which it has come to acquire while awake is evidently seamless.

During sleep, what is preserved is a *machine* which is continuous with the data bank upon which it draws, and much more mysteriously, is continuous also with the material substratum of its owner; the machine and its operator constitute a single, if highly polarised, entity; there is a continuum of engrams embedded within one and the same exotic substance. To say that it is a machine is to imply that its performance, while acting conservatively, is Von Neumann- and hence ultimately Turing machine- reducible. In principle, at least, this means that a machine of equivalent performance -equivalent in every way- could be constructed in the outside world, drawing only upon what conventional physics is able to supply. Once again, I'm speaking only of conservative performance. In actual fact, however, as I have sought to prove elsewhere, such a device would be physically beyond reach even given all of the matter of the cosmos; the enterprise would be throttled by steric hindrance, communication delays, not to

mention the threat of gravitational collapse. I suspect that the dependence of performance upon size might well crest out at some critical value beyond which further expansions would be counter-productive; how about a cubicle device of porous construction, 1 kilometre on the side in low earth-orbit?

To speak of mind and its owner as a machine is in no wise to demean either. No less an assumption could possibly account for the extraordinary *coherence* of human performance which is to a high degree predictable - though in terms of ends rather than means. Clearly, then, when we are acting completely conservatively what we are witnessing is a fantastic machine in action. But what of the phenomena of true (ie not merely adaptive) learning and creativity of all kinds which are by definition non-algorithmic? There can be no question of the machine being bypassed because such innovations very much depend upon the status quo which gets modified and enhanced, rather than replaced in the process. It is at this point that our machine acts like no other. Evidently, under some forms of exercise, the devise undergoes self-improvement; here once more, it must not be forgotten that the owner is himself a part of the machine with which he is continuous, rather than someone standing outside at the controls; another way of putting it is to say that the machine is an extension of himself. Quite something; a machine which can progressively upgrade itself without losing functionality for a single instant. There is no shut-down during which improvements are made; such is only possible because it's an inside job.

Nothing comes from nothing -so whence the Shannon-Weaver information which must come from somewhere? Does it come from the machine? Clearly not for in the process it would have to act non-algorithmically, hence exceeding its mandate. There can be but one answer. Whatever it is which vivifies our conscious moments, though embodying a mysterious second category of conscious interiority, is evidently itself no stranger to form and matter; how else would it be able to refashion the machine which it encounters? What all of this must surely mean is that the entering principle of enlivenment is *bimodal*, that is to say, *modally janus-faced*. Obviously this must have something important to contribute to the delicate question of the *Cartesian cut*; just exactly where is it to be sited? I believe that the envelope of options open to us is broader and more subtle than has hitherto been recognised or acknowledged. The innovative source must evidently enter through the subjective front end of the machine although creative advance can also come spontaneously by a kind of quasi-conscious crystallisation in which a long-pondered problem suddenly undergoes resolution.

Clearly, in its own way, conscious mind itself -unlike the latent form into which it retires during sleep- must also be bimodal, and I think it must follow that there is some kind of systematic *mapping* between the character of the interior experience and the engrammic configuration which is its immediate substratum. Such is not at all to imply a non-efficacious epiphenomenalism. We are confronted here by an entirely new kind of logic -a bimodal formalism. Clearly, it cannot be lurking within natural law, no matter however widely conceived, and it is not at all clear how any process of discovery is to be conducted. Many have asked: "what would it be like to observe a real-time sensory stream embodying the pattern of impulses circulating within the 'enchanted loom'"? The experience would have to be quite unlike any other. Could it be put into the service of unearthing the character of the bimodal mapping? Any success would presuppose a daunting constellation of 'ifs' calling alike for an evolution of a qualia taxonomy (where 'qualia' is taken to include every aspect of the qualitative aspect of experience) plus impressive advances in the technology of non-intrusive monitoring and presentation of cortical goings-on. But the conventional physicalist would have higher expectations concerning what might be learned from the experience. This is because for him, what is open (in principle) to observation within the cortex is the totality of the substratum of subjectivity, whereas to me it is but the crystallised extremum of that substratum.

There has always been a minority of respected voices urging the insufficiency of the present scientific canon. and therefore a need for its augmentation.

> ".....An adequate scientific theory of evolution must await the discovery and elucidation of new natural laws, physical, physicochemical and biological" Murray Eden (Hitching 1982) p.64
>
> "......We believe that there is a considerable gap in the neoDarwinian theory of evolution, and we believe this gap to be of such a nature that it cannot be bridged within the current concept of biology". Marcel P. Schutzenberger (Ibid p.64)

> ".....Current physics is incomplete in the strong qualitative sense, (not simply in the trivial quantitative sense of needing to do more work of the same kind). I believe we do need a radically different physics. This is not to say that physics is all wrong -that indeed would be absurd.....It may be, however, a limit case of a more complete physics, analogous to Newtonian physics being a limit case of relativistic physics." De Quincey (1995) p.223

> ".....We have been looking, up to now, for a physico-chemical interpretation of life. It may well happen that the discovery of new laws, and of some new principles in biology could result in a broad redefinition of our present laws of physics and chemistry and produce a complete change in our present point of view." L. Brillouin. [find title of book]

One may further anticipate that these new laws, far from merely adding a new and separate layer or stratum will, in fact *envelop* conventional law as a special and, one might almost add degenerate case. It is comforting to hear no less a sage than Louis de Broglie championing such a viewpoint:

> ".....I agree with Léon Brillouin that, if ever we manage to understand the true nature of life, it will only be on the basis of entirely new knowledge about the laws of nature and, doubtless, of new points of view and mental processes that are still beyond our present intelligence. Who knows but these new laws of biology -and Léon Brillouin seems to suggest just that- might not one day strike us as the most general laws, of which the laws of physics and chemistry are no more than particular instances." De Broglie (1962)

The need for an extension of the Lex Naturalis having been urged, there remain questions of *substance;* of logico-mathematical form; of categorical, qualitative or modal character and finally the means by which the dense coherence underlying life and mind come to take origin. We will be concerned, in the paragraphs which follow, only with some notion of the *envelope of options* open to us all. rather than with my own particular approach. I will return to this in the final chapter of this volume.

To start with the origin of the *substratum* and its physical nature. One thing, surely, which needs to be avoided is any suggestion of an ad hoc addition which lays an exotic substance atop the more ordinary kind which confronts us everywhere; to follow this line of speculation is to court the same kind of oil-on-water disjunction that was to bedevil earlier versions of Descartian dualism. Many forms of the much-derided 'vitalism' suffer from the same kind of excessive 'otherness'. What would seem to be more tailored to our needs would be an exotic form of matter which arose through something of the nature of a *phase change*, as when ice melts or liquid water boils. However we do need to be upon our guard in not pushing this analogy too far. Evidently the transition must be partial, indeed no more than marginal, else the conventional matter from which it took origin would suffer an alteration of character which would be quite evident -even, so to speak, to the naked eye. Exotic and conventional matter would have to move together, cooperatively and harmoniously, as indeed is evidently the case with our own brains. It is also hard to deny that exotic matter brings much of its influence to bear through the agency of *fields* of some kind -not too different in character than those to be found in the inorganic realm -eg electrostatic- though not reducible to any such fields.

> ".....The mind may be regarded as a field in the accepted physical sense of the term, but it is a non-material field, its closest analogue, perhaps, is a probability field.....Nor is it required to contain energy in order to account for all the known phenomena in which mind interacts with brain". Margenau (1984) p 97

Libet (1995) proposes a general mental field as an independent category, analogous to magnetic fields, which is normally brain wide, is in 'duplex' communication with the cortex (is both sensitive to, and efficacious upon cortical events], yet is not *directly* third-person detectable -though presumably some of its operational properties would be inferable from cortical signal patterns not otherwise explicable. Libet does not attempt to specify just how the field interfaces with the cortex, nor speculate upon its origin and metaphysical character; indeed, he points out that it is compatible with almost any philosophical mind-brain theory. He views Sperry's split

brain findings as more than a straw in the wind here, and has proposed an 'isolated cortical slab' experiment which might be a definitive test for the theory. If a small slab were to be *neurally* isolated from the rest of the cortex, and its stimulation produced mental phenomena, this would be proof that continuity with the rest of mind was being maintained by some exotic means.

Libet (Ibid) also points out that spatially distributed correlations of neural activity within 'loom' phenomena might underlie the internal subjective "binding problem", but surely this must be viewed as effect rather than as a cause. It seems that something may already have been found: "....Recent discovery of a widespread synchronisation of oscillatory neural responses to certain visual configurations.....has led to some speculation that a 'correlation' model might represent the neural coding for recognising a unified image in an otherwise chaotic background. This speculation is still to be tested". If confirmed, it would, as Libet suggests, be of the greatest interest. However, while indeed suggesting an appropriate neural *correlate* of the 'binding' problem we would have to assume that the kind of impinging mental field which Libet has proposed would be needed to account for that mysterious integral aspect of perceptual experience of which Josiah Royce wrote so eloquently:

> ".....One of the obscurest (notions). is the assumption that our mental states are composite in structure, made up of smaller states conjoined. This hypothesis has outward advantages which make it almost irresistibly attractive to the intellect, and yet it is inwardly quite unintelligible."
>
> "In other words, no possible number of entities -call them as you like, whether forces, material particles, or mental elements can sum themselves together. Each remains in the sum what it always was."
>
> "Take a sentence of a dozen words and take twelve men and tell to each one word. Then stand the men in a row, or jam them in a bunch and let each think of his word as intensely as he will. Nowhere will there be a consciousness of the whole sentence. Atoms of feeling cannot compose higher feelings any more than atoms of matter can compose physical things."
>
> ".....Aggregations are wholes only when they behave as such in the presence of other things. A statue is an aggregate of particles of marble, but as such it has no unity. no summing up of parts can make an unity of a mass of discrete constituents unless this unity exist for some other subject, not for the mass itself." Royce, quoted by James (1985)

Speaking personally, I can think of no experience which drives home a conviction that exotic fields are at work than a half hour spent in observing an active amoeba through a low-powered microscope. I have found it impossible to believe that contact forces -the only ones classically allowed- are alone responsible.

I take it absolutely for granted that the kind of phase change of which I am speaking is related both to chemical composition and molecular organisation; to believe otherwise would be to fall into the unfortunate error of *functionalism*. Obviously much of protoplasm provides exactly what is needed. I cannot prove that appropriately organised silicon chips could not equally do the trick, but can only remark that such would be an extraordinary coincidence.

With some trepidation, I would like to offer Liebig's views on the matter -coming to us across the span of a century [check date of Liebig's book]:

> ".....In [Liebig's] textbook , Animal Chemistry, he appears to agree with the mechanists that a living organism merely results from the component atoms and molecules being correctly situated relative to one another, and that a living organism could, at least in theory, be made in the laboratory. But he believed that when the atoms and molecules of a living organism are in their correct relative positions, a new force manifests itself. This vital force is the principle cause of the molecular reactions and movements at the basis of life. This force, he believed is inherent in all atoms and molecules, but only manifests itself in the complex structure of the cell"
>
> J.M Barry (1969)'

My reservations have to do with the way in which there seems to be a conflation between the needed vital substratum and the teleological drive which shouts at us from the activity of life and mind. It is as though matter had somehow swallowed the Platonic realm, so that the drive itself took origin from some phosphorescent chamber buried deep within the heart of matter. There very much *is* a principle of Elan, though it be of transcendent rather than material origin. I shall return to this again in the concluding chapter of this volume.

Given that we had our exotic substance, the next question confronting us would be this. If it is to be the substratum of mind, what kind of logic, what kind of mathematical formalism dominates the organisation of *engrams* which somehow preserve both the contents of mind and the personality of its owner? Is it simply a carbon copy of the principles of organisation which we find in the outside world (as exemplified by that substance of the cortex encountered by the neuroanatomist and physiologist) transferred to a new -and perhaps more delicate medium- or is it something more? The first strong hint that something different is indeed afoot centres upon the very elusive concept of *organism* which, some have insisted, is not at all the same thing as *aggregate*, *composition*, or *synthetic object.* But it is much easier to recognise it when one sees it than to bring the underlying mathematical canon into focus.

> ".....Biologists in their haste to become physicists, have been neglecting their business and trying to treat the organism not as an organism but as an aggregate.....if the concept of organism is of such importance as it appears to be, it is something of a scandal that we have no adequate conception of it. The first duty of the biologist would seem to be to try and make clear this important concept." Woodger [date?]

> ".....Biologists are right to reduce their problems to physics where this is possible. But biology has a fundamental unity of its own. Whitehead has shown the philosophical importance both in physics and biology of the concept of organism...." Dampier (1961)

Louis de Broglie suggests that within particle physics itself something of the distinction between aggregate and organism is already to be found, anticipating, as it were, is it were, the emergence of living forms.

> ".....[Quantum Physics] has shown there is a kind of complementarity between the concept of the individual unit, and the concept of the system. In Quantum Physics, therefore, the system is a kind of *organism*, within whose unity the elementary constituent units are almost reabsorbed. When forming a part of the system, then, a physical unit loses a large measure of its individuality, the latter tending to merge in the greater individuality of the system.....To make a real individual of a physical unit belonging to a system, then, it is necessary to take this unit from out of the system -to break the links which bind it to the total *organism".* de Broglie (1939)

The notion of the *unity* of the organism is closely related to that of 'holism'; both terms seem to hint at the fact that the unity in question points to something more than a hierarchy of layers *viewed* or *thought of* as in top-down rather than bottom-up terms. This holistic unity of organism seems to suggest a new kind of unit, a *unit-of-all* which is to be distinguished from the bottom-up units out of which the system is built, something which, in itself, and in its own way, is a kind of *source.* As L.L.Whyte makes very clear, we are confronted by a problem in need of fundamental *mathematical* clarification:

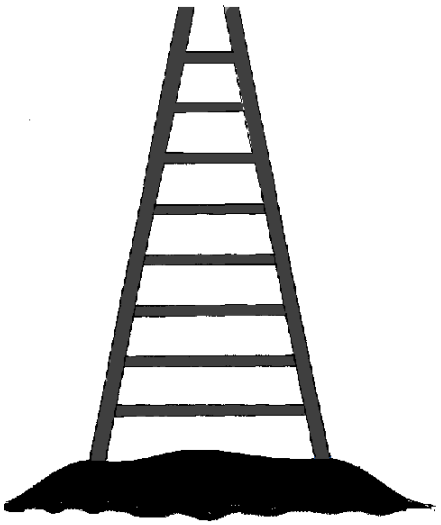
> ".....What is lacking is a mathematical conception of the character of the unity of the organism, and of organic subunits, a conception of the mathematical form of the type of unified ordering processes which is life. Until the mathematical form is identified, the 'unity of organism' remains a vague, intuitive heuristically infertile, macroscopic conception. But once [its].....form is known, a fresh chapter in the history of ideas will be opened and biology will be guided by a new paradigm." Whyte (1965)

This problem remains unsolved, and for the most part, untackled on the kind of terms which I believe Whyte had in mind.

My personal belief is that the right place to start is by considering the elusive character of our own psyche -an entity which is evidently the source of most of the mind over which it presides. In its role as source, we might think of it as the most general of concepts or ideas, one from which most of mind takes its origin. We might then back this up by an appeal to Royce's introspections quoted above. During such acts of perception and cognition one is conscious -at one and the same time- of an articulate field which at the same time is seen as a unity. This is a very mysterious matter which cries out for explanation.

A second formal mystery which seems peculiar to mind is the nature of concepts and ideas. These elusive entities seem to define each other -to the point where the richness of interconnections seems to dwarf that of their independent engrammic content. What kind of manifold of mind would be appropriate to such configuration? That these objects are quite mysterious is conveyed by such questions as 'where is the Jupiter symphony' or 'where is the English language? This is but one guise of the stubborn problem of *universals;* first recognised by Plato, it was to dominate the thought of the Schoolmen of the Middle Ages and remains unsolved to the present day.

(5) More on Stairways in the Mind.



It is my contention that we are indeed confronted by a stairway which, however, is bipolar, having two substrata each of which supports its own hierarchy. The one has already been given us by Shephard (1991); it is that limited to the conventional matter of the cortex, and might be thought of as providing those circulating currents of the 'enchanted loom' which the mind requires -not only in maintaining a two-way interface with the rest of brain and the body beyond, but also in support of internal thought. To say this is not a all to commit us to the notion of the cortex is *computer*, though it is certainly a *machine* of some sort. In figure 5 this hierarchy is depicted by a ladder which, for pedagogical reasons has been traded for the stairway. It is seen to be securely anchored, as it must be, to the rest of the brain and the body beyond. For the conventional physicist, its resources must bear the entirety of human performance unaided.

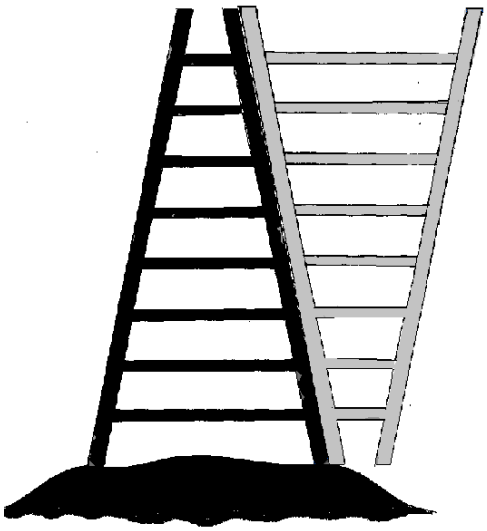
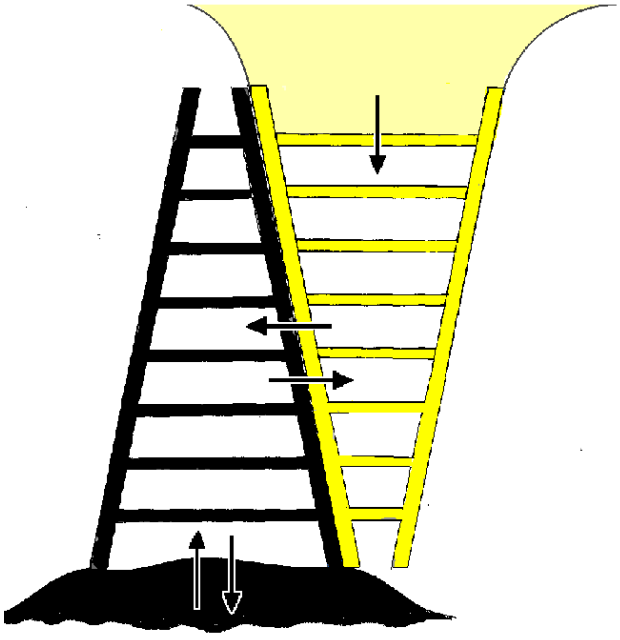


Figure 6 adds what I take to be the needed second ladder -this one of *mind*. It is physical, though constructed from exotic substance. It too is anchored to brain and body, though only through the ladder of the cortex with which it is seamlessly interfaced. The distinction between the bottom-up and top-down organisation of the two ladders is suggested, in the figure, by their respective convergence and divergence. One of the concerns which should be high up on our agenda is that of responding to Whyte's challenge -quoted above; just what is the mathematical canon underwriting the top-down logic of the second ladder? Recall that the top rung fundamentally overshadows all of those below -from which they derive; *this* ladder *starts* from the top. Solving this riddle may well call for breaking fundamentally new ground within the foundations of mathematics and should provide a field day for someone of Gödelian calibre.

Figure 6 depicts the mind/brain ensemble in the state of *latency* -that which survives during deep sleep. Figure 7 shows what happens upon awakening. The ensemble is now double-coupled; through the phenomena of the enchanted loom *below* and to the realm of transcendence *above*. The establishment intellectual must automatically dismiss this as de facto vitalism because of its break out from secularism. He is apt to find its conjunction with talk of top-down logic particularly disturbing -somehow reminiscent of the Middle Ages concept of the Great Chain of Being, in which God is the Top Link. I will say no more of this matter at the present juncture, save to add that such a step *need* imply no more than a reinstatement of the Platonic realm -in some form or other.



(6) The Snare of Naive Realism.

Anyone falling foul of this hazard is in danger of falsely reformulating mind-brain into its mind-body equivalent:

> ".....Conscious Purpose, as it exists in ourselves, is to be regarded as a highly evolved derivative of a more widely diffused natural condition or property, which we may call 'directedness'.....This physical integration, so characteristic of the living organism on its conscious side, implies the existence of a parallel physical integration, the two forming together a psychophysical unity.....In the characteristic unification of the organism, an integrative principle or property is acting which is similar in its essential nature to that of which we are conscious in mental life" Lillie [date?]

However we are left asking wherein resides the top-down unity of the somatic organism which so stubbornly inveigles the eye. There are few of us who would want to maintain that setting aside the mind, the physical organism is anything more than a society of cells with interconnections limited to what the autonomic and vascular systems can provide. This is to say that nothing of the nature of tissue-wide or organ-wide exotic fields

are at hand, wherein top-down logical configurations may reside. This would seem to bring us back to Hut's clocks which *produce* time; that is to say, the characteristic of top-down unity has to do with the *meaning* contributed by the observing eye, and is rooted in the purposefulness of organisation, ie for the way in which structure and organisation subserve *function.* Yet I believe one further -and highly speculative word- may be added. Just as the presence of a clock points back to a designing mind, doesn't a contemplation of what books of anatomy, physiologists and cytology so enchantingly reveal to us evoke that mind, willy nilly- has taken a major hand in the game. The issue here, of course is the whole question of the teleology and purpose which shouts at us from the spectacle of organic evolution and phylogeny. Some -those whom we might term 'weak creationists' and perhaps 'process' theologians, would wish to ground evolution upon a divine orthogenesis in which purpose and design enters through the guiding hand of the Master Craftsman. The only trouble is that evolution thought of in terms of mind appears as a process of 'forwards' groping with no hint or suggestion of a final goal to which we are heading - even though the depth of the look ahead is often impressive. Also, is the way in which adaptations, though remarkable, lack perfect coordination and timing. Millions of years after our adoption of the upright posture we are still plagued by haemorrhoids, slipped discs and inguinal hernias. Finally, the ugly blemish of parasitism is not easily squared with an image of divine goodness and perfection. A satisfactory explanation accounting for mind's presence in phylogeny has yet to be forthcoming. I offer some of my own speculations in the final chapter

(7) Wrap-up; The Way Ahead

Let me start this final section by repeating what Scott (1996) considers needs to be done in coming to terms with the problems of life, mind and society which bedevil us all;

> "...Like life, the phenomenon of consciousness is intimately related to several levels of scientific hierarchy, so the appropriate scientists -cytologists, electro-physiologists, neuroscientists, cognitive scientists, psychologists, psychiatrists, neurologists, anaesthesiologists, sociologists, and ethnologists- should be working together. It is difficult to see how this elusive phenomena might otherwise be understood".p184

Such appeals to the benefits of 'committee work' seem to resurface at rather regular intervals. The following letter, written by me a decade ago is self-explanatory:

> Dear Dr McKhann,
>
> I have just seen the lead article in the June 11 1987 issue of Washington Technology describing your plans for establishing a Mind/Brain institute.
>
> They sound depressingly orthodox, evoking a distinct deja entendu. The message is, that what's holding up progress is lack of communication between the experts, ie., that we have already pretty much gotten firm philosophical bearings, and only need to pull together as a team to make significant -if slow- progress.....
>
> On the contrary I believe there is every reason to doubt that Establishment presuppositions about the mind/brain problem can possibly be either true or productive. I enclose a synopsis of my recent book on the subject as an illustration of what I mean. If your proposal for a mind/brain institute had been that of establishing a team-of-one (yourself), and that your plan was to create a personal suite of offices (including a large library, a dumb-waiter connected to a staffed kitchen below), to enter, lock the door and throw away the key, you would have had me applauding, both as a fellow-professional and as a tax payer. I would gladly have proposed an annual salary of $250,000 and considered this a bargain, in consideration of the highly levered benefits which such strategies are apt to produce.
>
> There is a time for getting one's bearings and there is a time for committing oneself to the journey. They are different kinds of jobs and must be approached differently. The first is a

one-man job, the second more appropriate for team-work. It is a mistake to confuse the two. And they should be tackled in the above order. To quote Whitehead:

> "....No scientific enterprise can be more secure than the unconscious metaphysics which it tacitly presupposes."

There is, I believe, no greater mistake than that of believing that we need more information and more research to put us in a position where we can start to crystallise a contextual mind/brain theory.

Notwithstanding, the kind of institute you propose will serve the very useful purpose of broadening our base of knowledge -we can hardly learn too much about the neurone, for example- but put us on the right track with respect to solving the mind/brain problem- it certainly won't.

No, I'm not angling for a piece of the action at the institute; my potential contribution is about limited to the contents of this letter, plus the enclosure.

With best wishes, sincerely yours

I thought it was a rather nice letter -which has lost nothing of its relevance or urgency in the decade which has since elapsed. I never got a reply. Perhaps he never received it, or maybe he did and is hard at work in the way I have suggested. I hope so.

Neither Scott nor McKhann seems to feel the need for a fundamental paradigm switch which takes origin from ontology and metaphysics rather than in bringing these in as an after-thought when given a go-ahead signal from the neuroscience lab. Hut and Van Fraassen (1997) ask: "..Whether science will eventually be able to accommodate what seems to have been thrown out from the start is an open question" (p.169), and go on to plead: "..Let us take meaning to be equally fundamental as space and time" (p.171). During the past few decades, physicists have been offering us 'theories of everything' -stratospheric exercises in recondite mathematics- which have this in common; they say nothing of mind, and their authors seem unaware of the enormity of the omission. Mind is matter's most extraordinary production. This being the case, one would have thought that the quest for the discovery of physical reality's ultimate nature would benefit from this being born in mind from the start. If there is to be an intermodal accountability, then it ought to be that the raison d'etre of matter is to produce mind, and that therefore we should be asking ourselves what it is about matter which fits it for this role. Matter is of no intrinsic but of overwhelming *instrumental* value.

Cybernetics, Chaoplexology Addendum

The basic problem here is that of the shortfall (not always fully confronted) between the performance of organic systems at all levels -particularly that of the mind/brain ensemble- and the twice-limited resources that is all that their positivism provides. Firstly, the current gamut of natural law is not to be extended or elaborated *specifically* in the service of life and mind. On the surface, such a compulsive conservatism is not easily to be accounted for, given ample precedents within the history of science. From time to time, in the course of its evolution, physics has found itself confronted by phenomena not reducible to the scope of the canon currently at hand –so, appropriate extensions are envisioned and checked out.. In present-day parlance, we would speak of a *paradigm* change. Yet where the refractory performance of living things is concerned, the 'new paradigm' door is securely bolted and barred. Why so? One can only hazard the guess that to so favour the living realm might loosen the cork of the bottle within which the God of Isaac & Jacob has been confined. To make any such suggestion is to utter the 'v' word; one is branded as a vitalist.

But their added exclusion of any realm of Transcendence makes it impossible *in principle* to account for all of the trans-Gödelian phenomena of self-organization, creativity and true learning. *No* expansion of natural law –non whatsoever- could close this gap.

One might say that what they are trying to d is make bricks without both straw *and clay*. In interpreting this analogy, I would equate the clay with the body of dispositional mind -or memory, broadly conceived- that upon which the engrams of mind are embedded, and which survives during natural sleep or under narcosis. The straw is Eros and the contents of ψ-Logos; it brings with it both the second category of consciousness and subjectivity, together with the availability of the full gamut of trans-Gödelian resources.

How have they sought to account for the vast gap between the manifest phenomena of the organic realm and the meager resources to which they have limited themselves? For a start, by a flurry of panchrestons, catachreses –and just plain mantras. Here are some of those currently in favour: Memes, Networks, Cellular Automata, Chaos, Fractals, 'Complexology', Holograms, Heuristics, Prigogine's 'New Thermodynamics', Complex Adaptive Systems, Fuzzy Logic –and above all, 'Emergence'. Taken together, it is urged, surely they are sufficient to underwrite the requirements of a new paradigm without falling into the sin of vitalism or of mysticism. But just to cover their bet, they install their equivalent of 'God of the gaps' –or more generally, take forceful possession of the middle ground. The answers we're all looking or are buried amongst these –and other- hopefuls; the reason why there has been little success to date is that we have only so far 'scratched the surface' of what lies hidden within them. Occasionally, also to be heard are sotto voce echoes of a post hoc ergo propter hoc sort: 'These things *are* happening, aren't they? So *evidently* one o more of these largely unexplored options is at the bottom of it. With self-fulfilling promises of this kind, one can get away with murder –and that is exactly what is happening. But to come down to earth, all that we are being offered are straws in the wind. There is no sail-maker in existence who can weave them into the robust canvas needed to propel the enterprise forwards.

The transGödelian hiatus has been met by stratagems of evasion of every sought. These have been systematically scrutinized by Penrose; the field is an erudite one, yet it seems evident to me that Penrose has gotten the best of the game. Even should it turn out to be the case that the argument derived from the theorem is false, with respect to the matter at hand, the intellectual would still be confronted by the task of explaining how it is possible that algorithms –whatever these may turn out to be- have acquired trans-Gödelian characteristics.

Perhaps the option that most in their hopes upon, is complexity theory –in all of its man guises. This discipline, coupled to the notions of pan computation and that the ultimate reality is an ontology of *information*, is believed to hold the key that will open the door upon a final closure; One group of eminent scientists –including a number of Prizewinners- have christened all of these endeavours as 'the Third Culture' [?] –viewed as a paradigmatic advance upon current orthodoxy. The central ideas are somewhat as follows. As things get more complicated, so new levels of order *emerge* as each succeeding rungs of the ladder is mounted. So far, this is orthodox enough, following directly from Gödel's celebrated theorem. But now, something more starts to be added. What ultimately emerges, if we proceed far enough, is a *top-down* corpus of laws, i.e. that there's a novel but immensely powerful domain of mathematics 'up there' of which we have heretofore only caught a glimpse. This, it is important to emphasize, is to say a great deal more than that its just a top-down way of looking at what has arisen through bottom-up ladder-climbing. Such a holism is indeed what is evidently at work and which we are in need of bringing into focus. What to complexity people are claiming is that a bottom-up canon can furnish us with a novel holistic top-down mathematics. Davies comments that even though we were to some day come into a 'theory of everything' in physics:

> "……that would still leave this path of complexity, the synthetic or holistic way of looking at the world. There, what I see as the real excitement is the dissolving away of the distinction between physics and biology."

None has been a more articulate or influential contributor to this line of thought than Murray Gell-Mann; he particularly stresses the interaction between systems and their environment –particularly upon parts played by 'accidents' which get caught u into the system, to take a long-term hand in shaping their evolution:

> "……What I like to say is that the subject consists of the study of simplicity, complexity of various kinds and complex adaptive systems…..to describe the whole field, I've coined the word 'plectics' which comes from the Greek word meaning 'twisted' or 'braided'. The cognate Latin word *plexus* , also meaning 'braided' gives rise to 'complex', originally 'braided together'. The

related Latin verb *plicare,* meaning 'to fold' is connected with *simplex,* originally 'once-folded' which gives rise to 'simple'…….some day we'll have a full-fledged science with theorems and proofs……At the Santa Fe institute, we encourage not only the study of plectics but also a number of general habits of research: building staircases from the top as well as the bottom." [ibid] .

"……Many of us believe that self-organization is a general property -certainly of the universe and even more generally of mathematical that might be called 'complex adaptive systems'." J. Doyne farmer [ibid]

Stuart Kaufman, in striving to account for he origin of life in terms of chaos theory, adds: "……I suspect that there are emergent laws about how such systems work [ibid]".

"……By spontaneous order, or order for free, I mean this penchant that complex systems have for exhibiting convergent rather than divergent flow, so that they show an interesting homeostasis, and then to the possibility that natural selection can mold the structure of systems of this kind that will provide us with a macroscopic law that defines ecosystems, and I suspect may define economic systems as well." [ibid]

Goodwin also lays great stress upon the 'attractors' of complex theory, believing that organisms have arisen just because there were corresponding attractor within complexity theory which, given the shaping of natural selection, brought them forth. Some at least have called a halt to such extravagant *stretching:*

"……'all the beautiful we see in the world are just there for the taking; they just emerge out of the complex dynamical systems because the world is full of attractors'. The trouble with it is that it's hard to criticize. You can always say, after the event, that there must have been an attractor for whatever occurred –because if the world ends up in a particular configuration , then it must have been attracted to it." Nicholas Humphrey

Daniel Dennett, by way of rebuttal, asks whether such industrial products as the automobile came into existence from underlying laws of complexity; they only arose because there were attractors 'out there' in the formalism of complex systems which allowed and favoured their development:

"……I don't think there's anybody who thinks there are deep, fundamental laws of automotive engineering, but when Goodwin says there are laws of form in biology, he's making what I view as an equally implausible claim."

Francisco Varela [ibid] also complains about such stretching –with reference to Kaufman's initiative:

"……It doesn't seem to me that the book hangs together as a whole. There's too much of 'let's assume this, and let's assume that, and if this were right, then….'."

FOOTNOTES

[1]The 'n-body' problem (featuring a set of n astronomical bodies circulating around one-another) is a simple example of a chaotic system. Thus, one cannot tell in advance whether or under what circumstances one or more of the bodies may end up getting thrown clear of the system.. This n-body problem was long considered to be unsolvable by many -including Weierstrass- for all values of n greater than 2. However, a closed-form solution was recently obtained by Wang Qiu-Dong. This triumph is, however, of purely theoretical interest because the series solution converges much too slowly to be put to practical use.

[2]Fractals, following the discovery of the Mandelbrot set seem to have caused quite a stir, and are currently been touted as the master principle of fromalism and coherence behind just about every manifestation of complexity -stellar, geographic, organic and mental. What seems to be overlooked is that they are only productive in proportion as one approaches the fringes of organicism. Trees, fern leaves and galaxies are stick, surface, and three-dimensional scatterings and are mere societies of elements lacking the kind of cephalo-caudal polarisation found, for example, in our own bodies. No doubt there are fractal elements which can be teased out from its global complexity -but one can say this about anything. Fractal compression is being widely practiced, but mostly on images, that is, two-dimensional surfaces; it is hard to imagine you could fractally compress the human body so that it would reemerge properly interconnected, upon decompression. Even with images, it is not clear to what extent success is image-dependent. One would have more confidence if its advocates presented us with images which compressed poorly under this discipline. One suspects that other compression algorithms work equally well with those images which are appropriate, whether one is talking about fourier transforms or delta compression. Of course, the endless variety of the Mandelbrot set is awe-inspiring and provides the fractal votaries with their strongest debating point, namely at what profusion can issue from a simple generating formula. But again, all of the images flowing out of the Mandelbrot set have a certain strong family likeness; you don't suddenly see a human body float into view. I suspect that properly regarded, fractals are a shadow or image, a part of a far more comprehensive formalism which resides on the life/mind side of the equation.

[3]Kauffman describes a complex graph of N nodes (each of which can exist in one of two states) each of which is connected to k others. At each successive instant, the new state to be taken by each node is determined by a specified Boolean function. Examples of three such functions, in terms of their truth tables, are given below Kauffman 1995 p84

With reference to these tables, Kauffman derives a parameter P describing the constraint imposed by the Boolean function. It is at a minimum where the truth table yields 50% zeros and 50% ones -as in the first table in the figure- and is at a maximum for both of the remaining tables (the first corresponding to Logical-And and the second to Logical-Or).

It follows directly from the principles of combinatorics, that the number of possible states of such a network is 2^N - which clear becomes huge as N becomes large. Kauffman found that for large N with P = 0.5:

- When k = 1, Nothing happens (hardly surprising!)
- When k = N (ie., the graph is totally connected), the system settles into one of a number of cycles each of which encompasses a sequence of states equal to √(total of States). For an N of 200, each such cycle would be approximately 10^{30} -huge, but still small compared to the grand total of 2^{200} states.
- But if k = 2, the length of the cycles shrinks most dramatically to √N !! In other words, if N = 100,000, then the system will settle down to a cycle (which cycle depending upon the initial state of the system) of a mere √100,000 = 317 states (out of a total of $2^{100,000} = 1/10^{29,998}$ of the total number of states.

A	B	C	D	E
0	0	0	0	0
0	0	0	1	1
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	0
1	0	0	0	1
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	0
1	1	1	0	1
1	1	1	1	1

a

A	B	C	D	E
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	1
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

b

A	B	C	D	E
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

c

With reference to the latter, he says "I hope this blows your socks off. It does mine". Yes it does, Dr Kauffman, but I fail to see that it has anything to do with the origin of life.

He goes on to elaborate on this idea, showing that for values of K > 2, the value of P may be fine-tuned to the point where the system is neither rigid nor random, but hovers at the significant interface between the two -at the 'edge of chaos".

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